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No. 947

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NEW EQUIPMENT FOR TESTING THE FATIGUE STRENGTH  
OF RIVETED AND WELDED JOINTS

By W. Müller

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NEW EQUIPMENT FOR TESTING THE FATIGUE STRENGTH  
OF RIVETED AND WELDED JOINTS\*

By W. Müller

SUMMARY

The mechanical and electrical construction of a new experimental instrument for fatigue testing riveted and welded joints is described. This experimental device has the advantage of being able to stress, even with comparatively low magnetic exciter force, structural components in alternate bending by resonance vibrations up to incipient fatigue failure. Tests made with this experimental arrangement give rules for the most advantageous execution of joints with respect to choice of material, profile, type of riveting or welding, and form of joint.

INTRODUCTION

The fatigue strength, as obtained on the conventionally employed fatigue bending machines or pulsators on test bars with dissimilar surface condition, as, for instance, polished, turned, notched, or with fillets, is already known for a great many materials. The tendency now is to test the structural component itself as it is actually stressed in practice, rather than test bars. To insure positive results in such tests within reasonable time it will usually be necessary to choose the stress in the test specimen high enough so as to induce fatigue failure after a fatigue stress of about 1 to 14 days. Such tests disclose the endangered points of the part comparatively quickly and enable in many cases con-

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\*"Neue Versuchseinrichtung zur Prüfung der Ermüdungsfestigkeit von genieteten bzw. geschweissten Knotenpunktverbindungen." From a special reprint of Schweizer Archiv, 1937, no. 10.



struction of the part so that it produces the greatest possible life for a specified stress. The experimental device described hereinafter serves to study the joints frequently employed in airplane and car design for their fatigue resistance.

### MECHANICAL STRUCTURE

The testing of such parts requires different testing equipment, depending upon the type of stress.

In the subsequently described test equipment great value was placed upon a sinusoidal course of the alternating bending stresses in time rate and to the occurrence of the vibrations in rhythm of the natural frequency of the test body. This is most readily obtained by forming the joint into an oscillating pendulum on which the maximum amplitude is preserved by synchronously acting exciter forces.

Figure 1 shows the employed test arrangement whose construction is represented schematically in figure 2. The joint K to be tested is attached to a base plate with flanges and bolts. The upper part of this joint carries the flywheel mass SM, which also swings during the test and gives the pendulum a silent, steady motion. The excitation and preservation of the vibrations is achieved by two magnets  $M_1$  and  $M_2$  operating in opposite tempo to each other, which alternately pull the pole piece  $P_1$  and  $P_2$  downward, stretch the wire  $D_1$  and  $D_2$ , and pull the vibrating part of the joint to the left or right. To insure complete utilization of the magnetic pulling forces the air gap between magnet and pole piece must remain as small as possible even during the vibration. The simple wire joint preserves a lever ratio at which the pendulum of the joint is able to oscillate at high amplitude even by small pole piece motion. The two change-over contacts  $U_1$  and  $U_2$  control indirectly, i.e., across the electric oscillator, the exciting current.

### MODE OF OPERATION AND CONSTRUCTION OF

### THE ELECTRIC OSCILLATOR

With a suitable electric hook-up (reference 1) de-



signed by the author in 1933\* it was possible to excite the two magnets by two current impulses out-of-phase by one-half vibration period (fig. 3), so that the two magnets operate alternately. For the production of these two out-of-phase, pulsating direct currents, rectifier tubes, which in the employed hook-up serve as relay, were resorted to. Figure 4 illustrates the basic wiring diagram of such a tube, cathode K being heated by an incandescent lamp filament F. Opposite cathode K is the positively charged anode A, which has the tendency to attract the electrons radiated from the cathode. Between the two electrodes is the control grid G, whose potential can be changed by the control contact D. If the control contact is open the control grid has, because of predominately negative bias voltage ( $-G > +G$ ), a negative potential, by which the electrons emanating from the cathode are dammed up and prevented from passing to the anode. Closing the control contact simultaneously short-circuits the negative grid voltage ( $-G$ ) across the current limiting resistance  $R_1$  and places the positive potential of the bias battery ( $+G$ ) direct on the control grid, thus speeding up the electrons sent out by the cathode on their way to the anode and finally close the circuit of magnet M. The transport of the electrons in the tube is much facilitated by the enclosed mercury vapor, making it possible to control considerable currents with comparatively small tubes. As simple as the ignition of this tube is, the much more difficult is it to interrupt the current impulse again, because, according to experience, restraining the current of the electrons by changing the grid potential is insufficient; interruption of the current requires a brief disconnection of the positive anode potential.

With a suitable hook-up, such as in figure 5, it is possible to superpose a negative potential on the positive of the operating anode by means of a second, newly ignited electron tube across a condenser combination ( $C_A$  and  $C_L$ ), through which the first and hence also the current of the electrons in the first tube is interrupted. With two rectifier tubes, condensers, resistances, and bias batteries it is thus possible to control two currents in alternating synchronism. The electric vibrator is illustrated in figure 6.

The vibrator requires an alternating current of constant voltage (about 400 volts) and 0.2 ampere, taken from a specially designed rectifier conformal to figures

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\*Unpublished correspondence of the author with the Siemens-Schuckert-Werke, Berlin, Nov. 23, 1933.



7 and 8. It consists of a transformer T (for producing the necessary alternating E.M.F.), a rectifier tube G and a filter (condensers C and choke D) for smoothing the alternating current.

#### VIBRATION COUNTER AND AUTOMATIC STOPPING DEVICE

When making vibration tests it is desirable to know the number of vibrations of a piece up to incipient fatigue failure. With this in mind we designed a small synchronous motor (fig. 9), which revolves in synchronism with the vibrations and drives a counting mechanism Z across a small worm wheel. The current impulses in the armature of the electromagnet M are the same as in one of the exciter magnets, thus producing a pulsating magnetic field in the air gap which has the tendency to attract the nearest tooth of the iron rotating magnet wheel. These rhythmically appearing tractive forces turn the rotating magnet wheel in such a way that for each swing of the pendulum, i.e., at each current impulse in the magnet, the magnet wheel is turned by one tooth division. The total number of swings of the pendulum can be computed from the reading of the counter, the worm gear ratio and the number of teeth of the rotating magnet wheel.

When fatigue failure occurs in the test piece, the elastic constant of the pendulum is reduced until the vibrations are finally interrupted and with it also the sequence of the periodic current impulses. This causes the rotating magnet wheel to stop and the metal ball K in the bore of the magnet wheel which during the rotation of the wheel was whirled radially outward, rolls diagonally downward, touches the contact wire D and closes the relay circuit across slip ring S and brush B, and so disconnects the electric vibrator from the network.

#### EXPERIENCES WITH THE TESTING MACHINE

The vibration tests made so far on 65 riveted and welded joints have shown that, properly handled, the machine is dependable and fully capable of meeting the requirements asked without serious disturbances during more than 3,500 hours of operation.



The performance of the existing vibrating machine is sufficient to maintain riveted and welded light alloy joints of double U section with an inertia moment of  $10.6 \text{ cm}^4$  at a frequency of 9 to 11 vibrations per second and a maximum bending stress of 7 to 10  $\text{kg/mm}^2$  in vibration.

With properly designed mechanical driving system the fatigue strength of test bars of any dimension, such as standard round or flat bars, plate sections, cast girders, line wires necessary for the transmission of electrical energy, or even main system cables, can be determined.

The findings thus far permit some important conclusions regarding the fatigue strength of the different joints. Thereby the number of vibrations obtained at a certain alternating bending stress up to incipient fatigue failure was used to plot the pertinent fatigue curve. On the other hand, the position of the starting point as well as the course of the fatigue failure indicates the most endangered spot of the joint from which it can be seen whether or not stress peaks occur directly next to the rivet hole of flight alloy rivet joints as it may be theoretically assumed.

Translation by J. Vanier,  
National Advisory Committee  
for Aeronautics.

#### REFERENCE

1. Bauder, R., and Makh, H.: Zeitschr. für Elektrotechnik und Maschinenbau, no. 36, 1934.



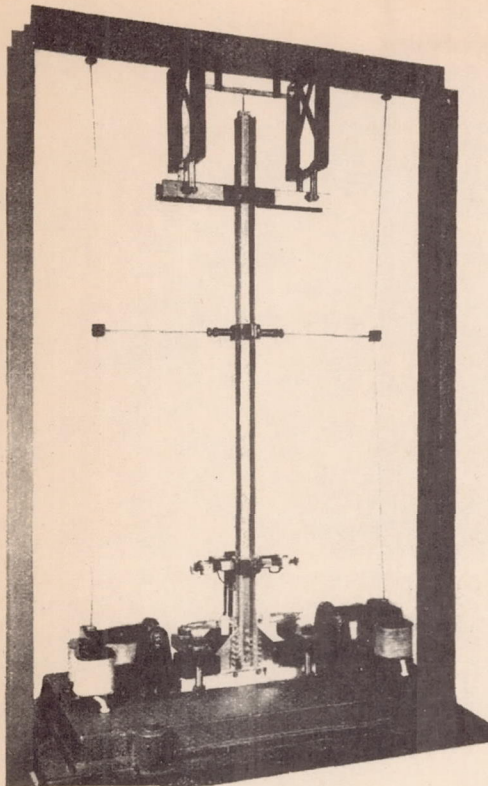


Figure 1.- Vibration machine for testing joints.

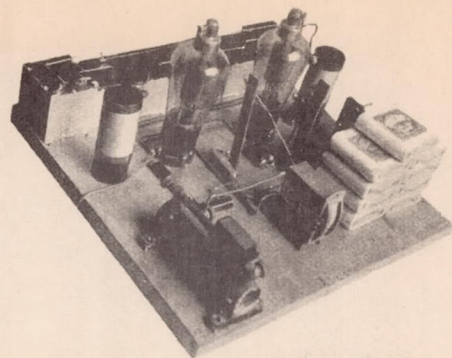
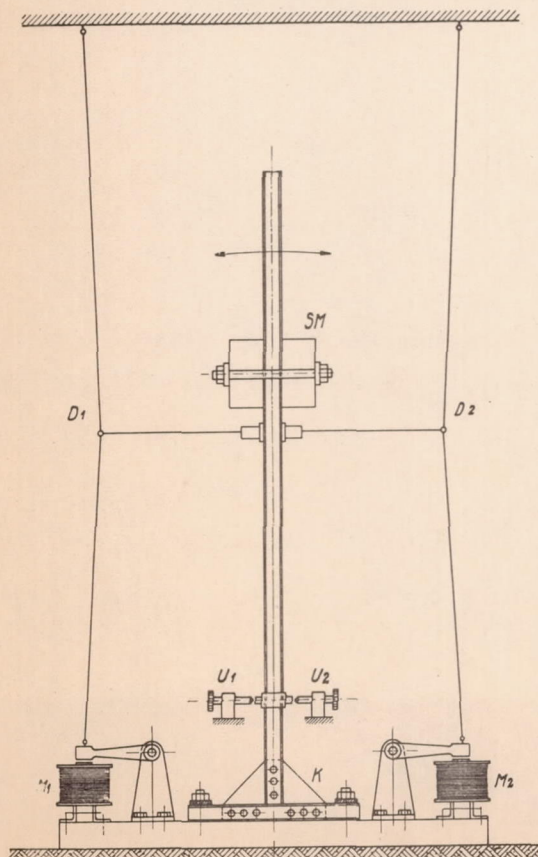


Figure 6.- View of electric vibrator.

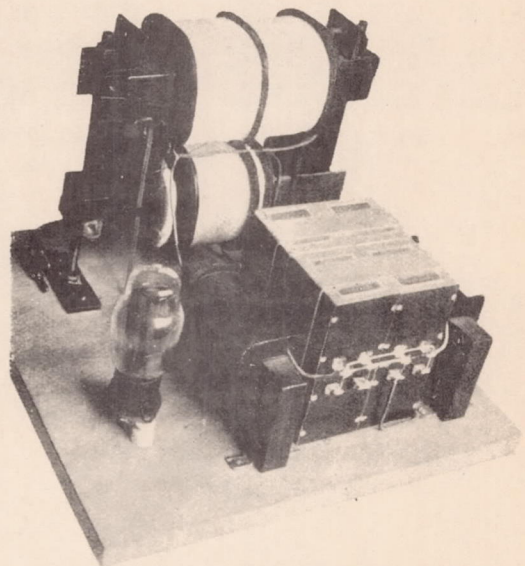


Figure 8.- View of rectifier.

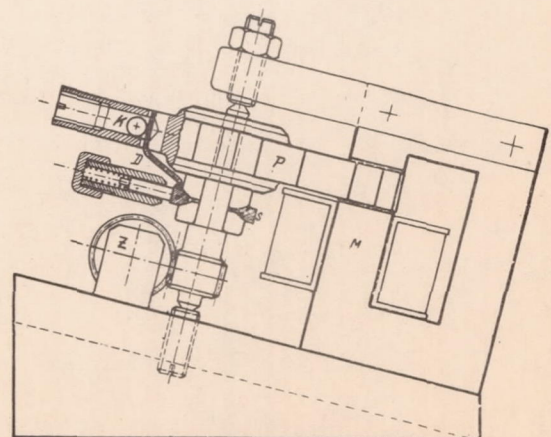


Figure 9.- Schematic drawing of vibration counter with automatic arresting mechanism.

Figure 2.- Schematic representation of joint testing machine.

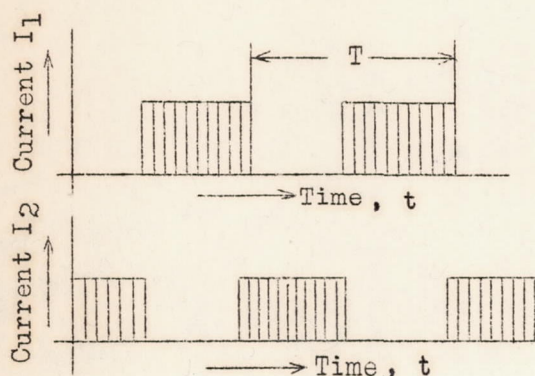


Figure 3.- Rate of magnetizing currents.

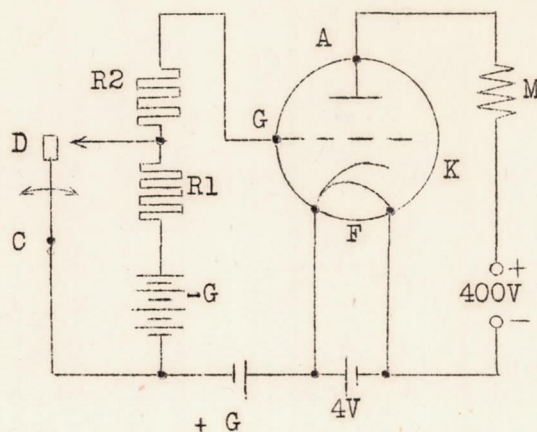


Figure 4.- Basic hookup of current rectifier tube.

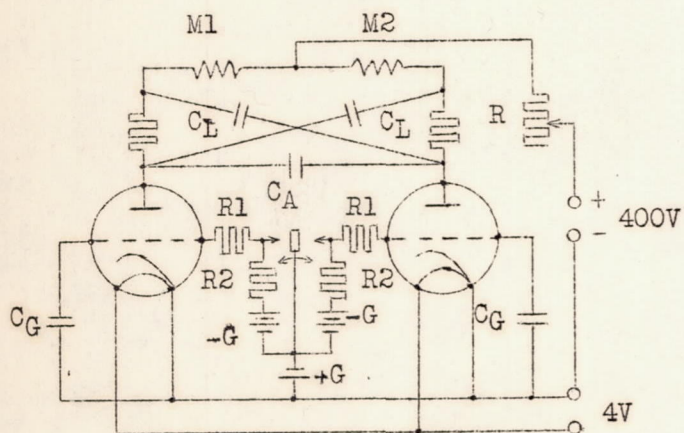


Figure 5.- Wiring diagram for electric vibrator.

Figure 7.- Wiring diagram for rectifier.

